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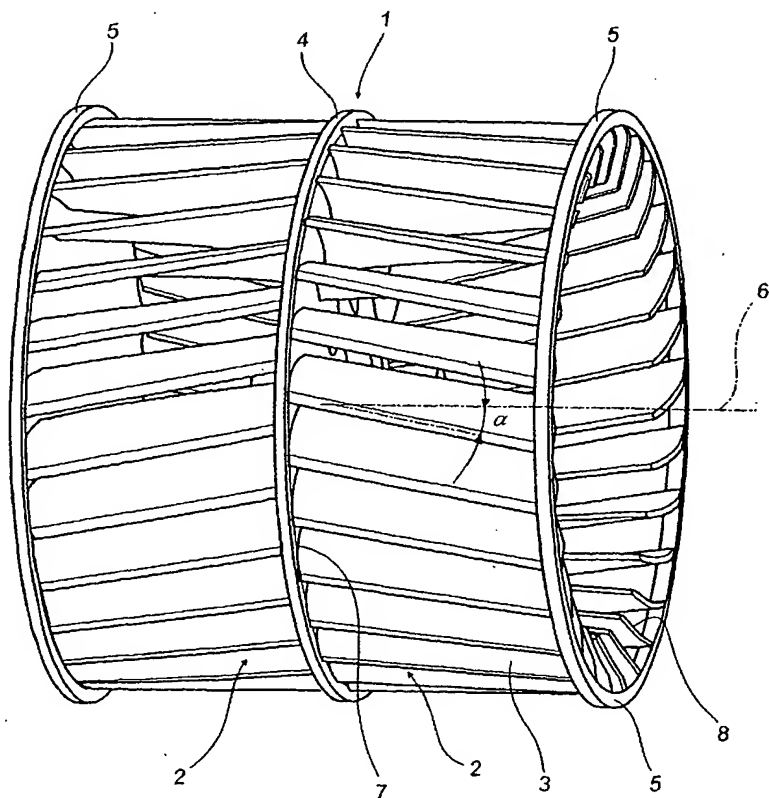
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(54) Title: A CENTRIFUGAL FAN IMPELLER WITH BLADES INCLINED RELATIVE TO THE AXIS OF ROTATION



(57) Abstract: The invention relates to a centrifugal fan impeller (1) having an axis of rotation (6) and comprising one or more modules (2). Each module (2) comprises a mounting disc (4), at least one connecting ring (5) and a plurality of blades (3) extending between the mounting disc (4) and the connecting ring (5). The blades (3) are connected to the disc (4) and ring (5) at an angle ( $\alpha$ ) relative to the axis (6) of the impeller (1). The angle ( $\alpha$ ) at which the blades (3) are inclined may range from 5 to 30 (sexagesimal) degrees and the blades (3) may be rectangular or trapezoidal in shape depending on the type of performance required: improved capacity with rectangular blades or improved pressure head and acoustic properties with trapezoidal blades. Top performance is thus combined with acoustic comfort.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

Description

A centrifugal fan impeller with blades inclined relative to the  
axis of rotation

Technical field

The present invention relates to an impeller for a centrifugal fan whose blades are inclined relative to the axis of rotation of the impeller itself.

5       The impeller according to the invention can be used in fans for several different applications, for example, for moving air through a heat exchanger in a motor vehicle heating system. The invention can also be applied to fans for home air conditioning or heating installations.

10

Background art

Impellers for fans of this type must meet several requirements, including: low noise; good noise spectrum distribution; high efficiency; dimensional compactness; good  
15       pressure head and capacity.

Document EP-0 816 687 discloses a centrifugal fan having an impeller with inclined blades.

The blades are arranged on an annular surface around the impeller axis. Each blade has a tapering section and is curved  
20       outward, that is to say, has edge portions that are curved outward.

This constructional design, although it effectively reduces noise, is difficult to make by plastic injection moulding. Thus, document EP-0 816 687 also proposes a specific method for  
25       manufacturing the impeller and moulds especially designed for this purpose.

The present invention has for an aim to provide an improved, low-noise centrifugal fan impeller with inclined blades which offers top performance in terms of pressure head and capacity and

which, at the same time, is easy to construct.

#### Disclosure of the invention

According to one aspect of it, the present invention  
5 provides a centrifugal fan impeller with inclined blades as  
defined in claim 1.

The dependent claims refer to preferred, advantageous  
embodiments of the invention.

#### Brief description of the drawings

The accompanying drawings illustrate embodiments of the  
present invention without limiting the scope of its application,  
and in which:

Figure 1 is a perspective side view of the impeller  
15 according to the present invention;

Figure 2 is a perspective front view of the impeller of  
Figure 1;

Figure 3 is a side plan view of a blade forming part of the  
impeller of Figure 1;

20 Figures 4 and 5 illustrate sections, respectively at the  
root and at the end of a blade forming part of the impeller of  
Figure 1;

Figure 6 is a sound spectrum diagram of a prior art  
impeller;

25 Figure 7 is a sound spectrum diagram of the impeller of  
Figure 1; and

Figure 8 is a front view of the impeller of Figure 1.

#### Detailed description of the preferred embodiments of the invention

30 Below are short definitions of the terms used to describe  
the impeller according to this invention:

the leading edge (A) is the line that delimits the front of  
the blade, that is to say, the first part of the blade profile to  
come into contact with the fluid flow;

35 the trailing edge (U) is the line that delimits the back of  
the blade, that is to say, the last part of the blade profile to  
come into contact with the fluid flow;

the chord (L) is the length of the line joining the ends of the arc extending from the leading edge to the trailing edge for an aerodynamic profile of the blade section at the intersection between the blade and a plane perpendicular to the axis of rotation of the impeller;

the centre line (MC) of the blade is the line joining the midpoints of the chords L at the different radiuses;

the inclination ( $\alpha$ ) of the blade is the angle made by the centre line (MC) of the blade and the axis of the impeller;

the camber (f) is the longest perpendicular line to the chord (L), measured from the chord (L) to the profile or camber line of the blade; the position of the camber (f) relative to the chord (L) may be expressed as a percentage of the length of the chord itself.

With reference to Figures 1 and 2 of the accompanying drawings, the numeral 1 denotes in its entirety the impeller according to the invention.

The impeller 1 may consist of two or more modules 2, each of which comprises a plurality of blades 3 extending between a mounting disc 4 and at least one connecting ring 5. The blades 3 are connected to these components at an angle  $\alpha$  relative to the axis 6 of the impeller 1. The angle  $\alpha$  may range from 5 to 30 (sexagesimal) degrees and is preferably 10 degrees.

The blades 3 of two adjacent modules 2 may be inclined in the same direction or in opposite directions. Further, the blades 3 of one module 2 are preferably offset with respect to those of the adjacent module 2, that is to say, the end of one blade 3 of one module 2 is approximately half way along the space between two blades 3 of the adjacent module 2.

In one preferred embodiment, the impeller 1 is designed to be mounted in a centrifugal fan which sucks fluid in from both sides.

In another embodiment which is not illustrated, air is sucked in from only one side of the fan, whilst the blade 3 mounting disc 4 is located on the opposite side to that where air is sucked in. In the latter case, the impeller 1 may comprise two or more modules 2 placed side by side.

The geometrical characteristics of each blade 3 are illustrated in Figures 3 to 5.

Figure 3 illustrates a blade 3 in a straightened plan view. The blade 3 is basically trapezoidal in shape but it might also be rectangular to enhance capacity compared to head.

The blade 3 comprises a straight leading edge A, inclined at an angle  $\beta$  relative to the axis 6 of the impeller 1, a straight trailing edge U, parallel to the axis 6 of the impeller 1, a root 7 attached to the 4 and an end 8 connected to the ring 5.

The angle  $\beta$  at which the leading edge 4 is inclined may range from 0 degrees, in the case of rectangular blades 3, to 40 (sexagesimal) degrees.

The rectangular or trapezoidal shape of the blades 3 depends on the type of performance required: rectangular blades provide improved capacity, while trapezoidal blades achieve greater head and better acoustic properties.

A preferred value for the angle  $\beta$ , which provides excellent performance in terms of capacity, pressure head and acoustic properties is 12.65 degrees.

The blade 3 extends for a length L, the profile of the blade 3 has a straightened length W1, measured along the centre line of the profile, at the root 7, and a straightened length W2 at the end 8.

The lengths W1, W2 of the profiles expressed as ratios of the length L are the following:

W2 between 0.3 and 0.5 of the length L, preferably 0.35;

W1 between 0.3 and 0.8 of the length L, preferably 0.70.

Figures 4 and 5 illustrate sections of the blade 3 profile at the root 7 and at the end 8, respectively.

The curvature of the centre line 9 of the profile at the root 7 is defined by the equation

$$Y = Y_0 + \bar{a}_1(x - x_0) + \bar{b}_1(x - x_0)^2 + \bar{c}_1(x - x_0)^3 + \bar{d}_1(x - x_0)^4$$

where  $\bar{a}_1 = -\frac{1}{95,6}$ ;  $\bar{b}_1 = \frac{1}{27,9}$ ;  $\bar{c}_1 = -\frac{1}{61500}$ ;  $\bar{d}_1 = \frac{1}{32300}$ .

The profile has a chord C1 of 21.488 mm, a constant

thickness S1 of 1.1 mm and a camber f1 of 4.20306 mm between the centre line 9 and the chord C1.

The curvature of the centre line 10 of the profile at the end 8 is also defined by the equation

$$Y=Y_0+\bar{a}_1(x-x_0)+\bar{b}_1(x-x_0)^2+\bar{c}_1(x-x_0)^3+\bar{d}_1(x-x_0)^4$$

where the constants are the same as those stated above.

The profile has a chord C2 of 14.154 mm, a constant thickness S2 of 1.1 mm and a camber f2 of 1.5033 mm.

10 The cambers f1 and f2 are approximately half way along the respective chords C1 and C2, these positions being specified by the values lf1, lf2 in the table below.

15 The values of thickness S1, S2 and of camber f1, f2 of the profiles expressed in relation to the chords C1 and C2 are the following:

S1 between 5% and 8% of the chord length C1, preferably 6%;

f1 between 10% and 15% of the chord length C1, preferably 12%;

S2 between 6% and 10% of the chord length C2, preferably 8%;

20 f2 between 10% and 15% of the chord length C2, preferably 12%.

25 The chord C1 of the profile at the root 7 makes an angle  $\gamma_1$  with the radius R1 measured at the leading edge A. The angle  $\gamma_1$  may range from 50 to 80 (sexagesimal) degrees and is preferably 65.2 degrees.

The chord C2 of the profile at the end 8 makes an angle  $\gamma_2$  with the radius R2 measured at the leading edge A. The angle  $\gamma_2$  may range from 33 to 63 (sexagesimal) degrees and is preferably 48.2 degrees.

30 The description below refers to a preferred embodiment of an impeller according to the present invention without restricting the scope of the inventive concept. The impeller 1 illustrated in the accompanying drawings is made up of two symmetrical modules 2 with lateral suction.

35 Each module 2 has twenty-eight blades, which are offset with

respect to those of the adjacent module 2, has an outside diameter of approximately 99 mm and is approximately 44 mm wide.

The impeller 1 according to the present invention rotates preferably in the direction indicated by the arrow S in Figure 8, that is to say, in the direction such that, when the impeller turns in that direction, the leading edge A of the blades 3 - on the innermost diameter - is behind the trailing edge U - on the outermost diameter.

This configuration gives the best results in terms of silent operation and performance of the impeller 1.

All the characteristic values of the proposed preferred embodiment of the fan blade 3 according to the invention are summarised in the table below, where

	C1, C2	indicates the chord length;
15	f1, f2	indicates the camber;
	lf1, lf2	indicates the camber position relative to the chord C1, C2;
	S1, S2	indicates the profile thickness;
20	W1, W2	indicates the straightened length of the profile;
	$\alpha$	indicates the angle made by the centre line MC of the blade and the axis 6 of the impeller;
	$\beta$	indicates the angle made by the leading edge of the blade 3 and the axis 6 of the impeller;
25	$\gamma_1, \gamma_2$	indicate the angle made by the profile of the blade 3, at the root and end of the blade respectively, with respect to an impeller radius R1, R2 passing through the leading edge of the profile.

30

Position/value	Root	End
C1/C2	21.488 mm.	14.154 mm.
F1/f2	4.203 mm.	1.503 mm.
Lf1/lf2	53.92%	41.44%
S1/S2	1.1 mm.	1.1 mm.



$\alpha$	10°	10°
$\beta$	12.65°	12.65°
$\gamma_1, \gamma_2$	65.2°	48.2°

Figures 6 and 7 illustrate the results of tests in which a conventional straight-blade impeller (Figure 6) was compared with an impeller made according to the present invention (Figure 7), both impellers having the same capacity and pressure head.

The tests showed a reduction in sound level of around 1 dB(A) and a significant improvement in terms of acoustic comfort.

In this connection, it should be remembered that the sensitivity of the human ear is a function of two main variables: frequency and sound pressure level.

The sensitivity of the human ear decreases at low frequencies, increases at medium frequencies and decreases again at high frequencies. It is therefore possible to create graphs of the perceived intensity (loudness) of sound, commonly known as "equal loudness curves", used, for example, by national and international standard organisations.

The impeller according to the present invention makes it possible to shift the sound pressure level towards frequencies that are less disturbing to the human ear, which, in other terms, means that the sound made by the impeller is more "pleasant".

The invention described can be subject to modifications and variations without thereby departing from the scope of the inventive concept, as defined in the claims herein.

Moreover, all the details of the invention may be substituted by technically equivalent elements.

Claims

1. A centrifugal fan impeller (1) having an axis of rotation (6) and comprising one or more modules (2), each module (2) comprising a mounting disc (4), at least one connecting ring (5) and a plurality of blades (3) extending between the mounting disc (4) and the connecting ring (5), the blades (3) being connected to the disc (4) and ring (5) at an angle ( $\alpha$ ) relative to the axis (6) of the impeller (1), the impeller being characterised in that the angle ( $\alpha$ ) at which the blades (3) are inclined may range from 5 to 30 (sexagesimal) degrees.
2. The impeller according to claim 1, characterised in that the angle ( $\alpha$ ) at which the blades (3) are inclined is 10 (sexagesimal) degrees.
3. The impeller according to claim 1 or 2, characterised in that each blade (3) is substantially trapezoidal in shape when seen in a straightened plan view.
4. The impeller according to claim 1 or 2, characterised in that each blade (3) is substantially rectangular in shape when seen in a straightened plan view.
5. The impeller according to claim 3, characterised in that each blade (3) has a straight leading edge (A) inclined at an angle ( $\beta$ ) ranging from 0 to 40 (sexagesimal) degrees with respect to the axis (6) of the impeller (1).
6. The impeller according to claim 3, characterised in that each blade (3) has a straight trailing edge (U) parallel to the axis (6) of the impeller (1).
7. The impeller according to claim 3, characterised in that each blade (3) has a straight leading edge (A) inclined at an angle ( $\beta$ )

of 12.65 (sexagesimal) degrees with respect to the axis (6) of the impeller (1).

5 8. The impeller according to any of the foregoing claims, characterised in that the profile of each blade (3) at the root is inclined at an angle ( $\gamma_1$ ) ranging from 50 to 80 (sexagesimal) degrees.

10 9. The impeller according to any of the foregoing claims, characterised in that the profile of each blade (3) at the end is inclined at an angle ( $\gamma_2$ ) ranging from 33 to 63 (sexagesimal) degrees.

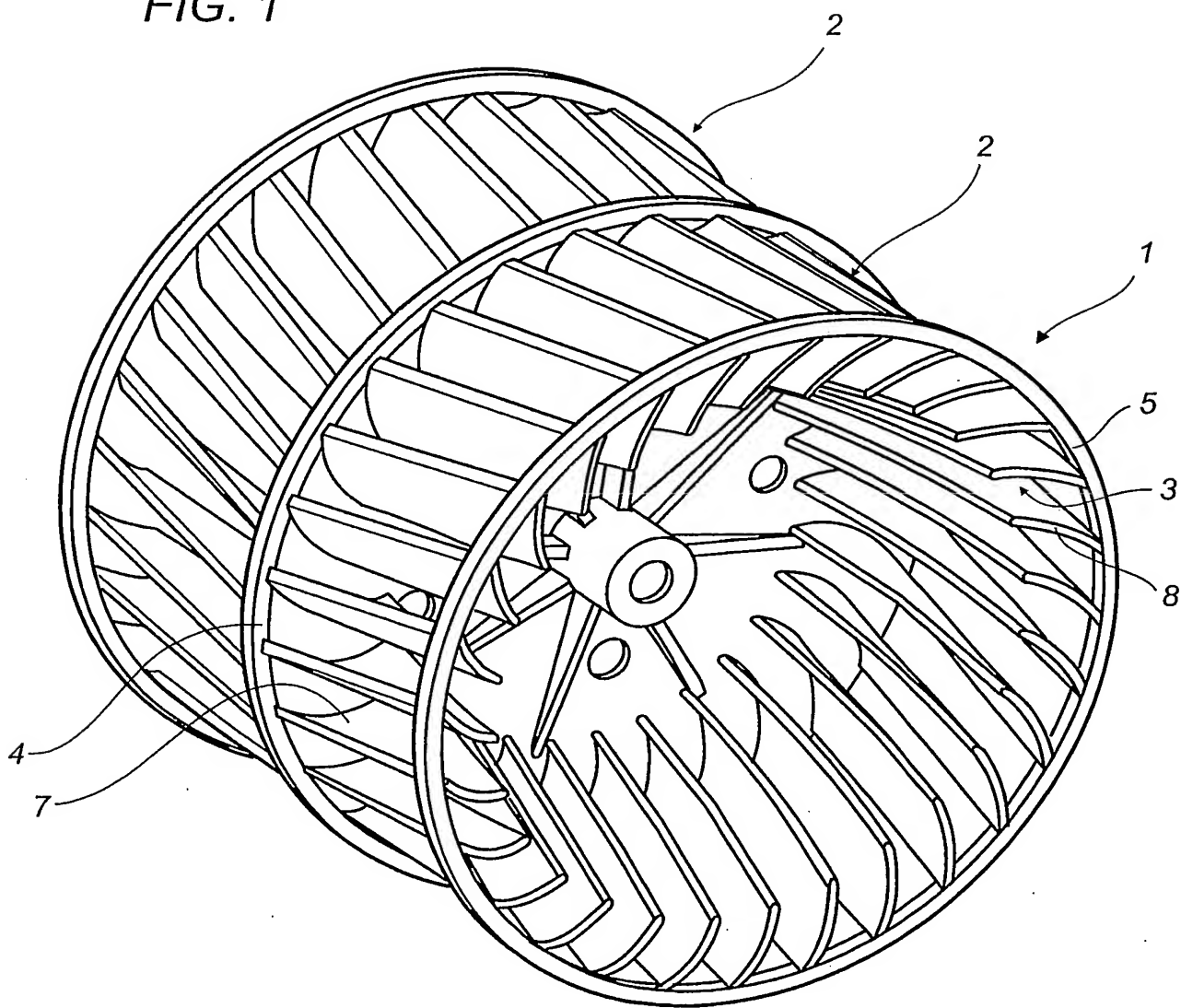
15 10. The impeller according to any of the foregoing claims, characterised in that the profile of each blade (3) at the root is inclined at an angle ( $\gamma_1$ ) of 65.2 (sexagesimal) degrees.

20 11. The impeller according to any of the foregoing claims, characterised in that the profile of each blade (3) at the end is inclined at an angle ( $\gamma_2$ ) of 48.2 (sexagesimal) degrees.

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FIG. 1

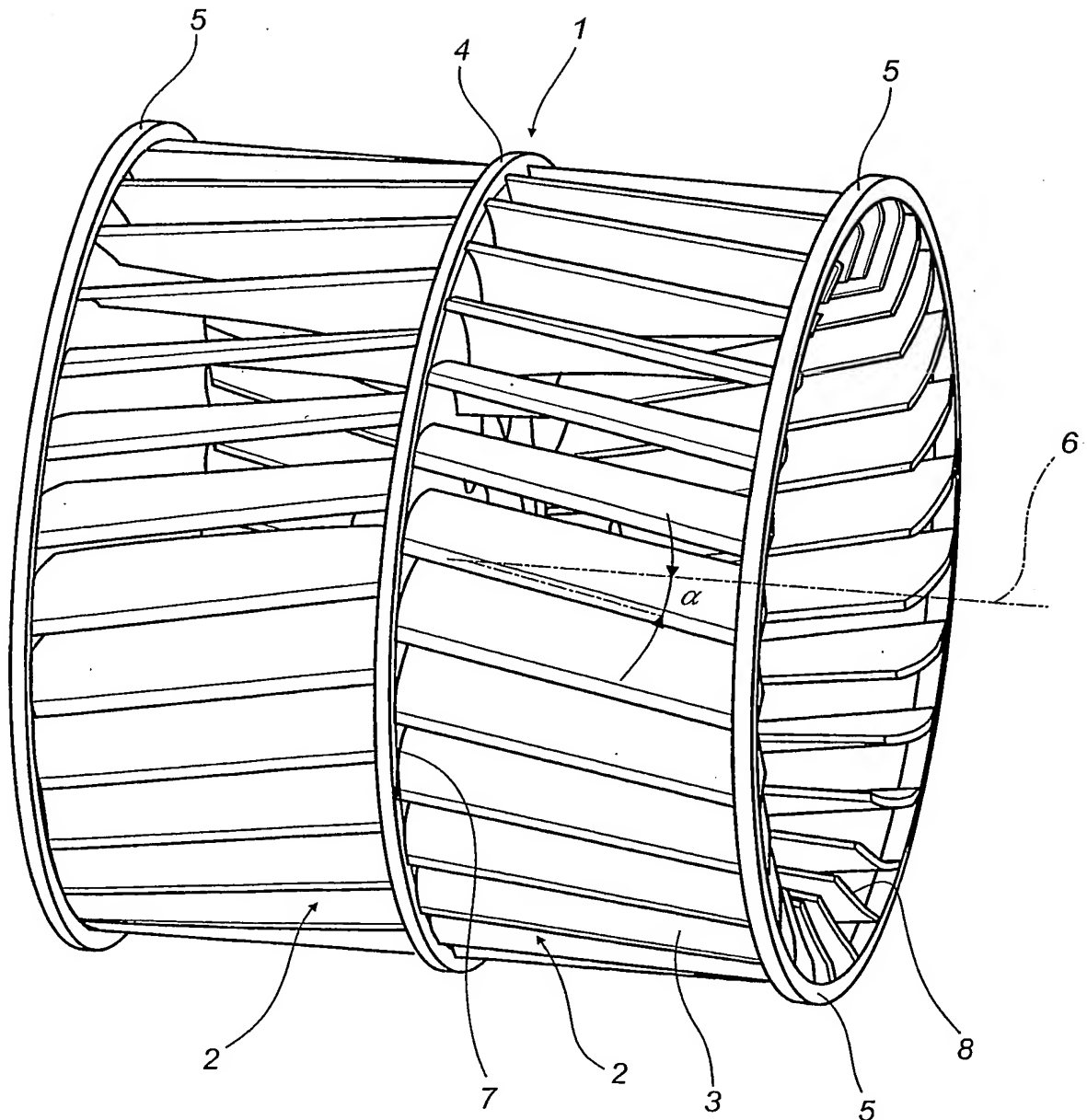


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FIG. 2



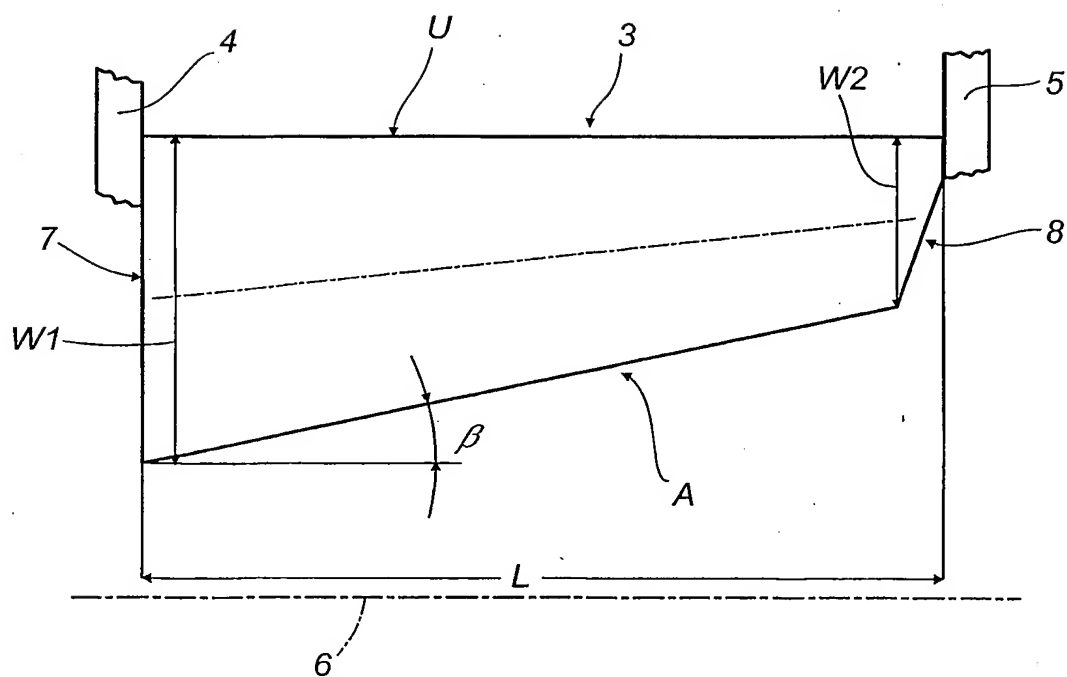
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FIG. 3



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FIG. 4

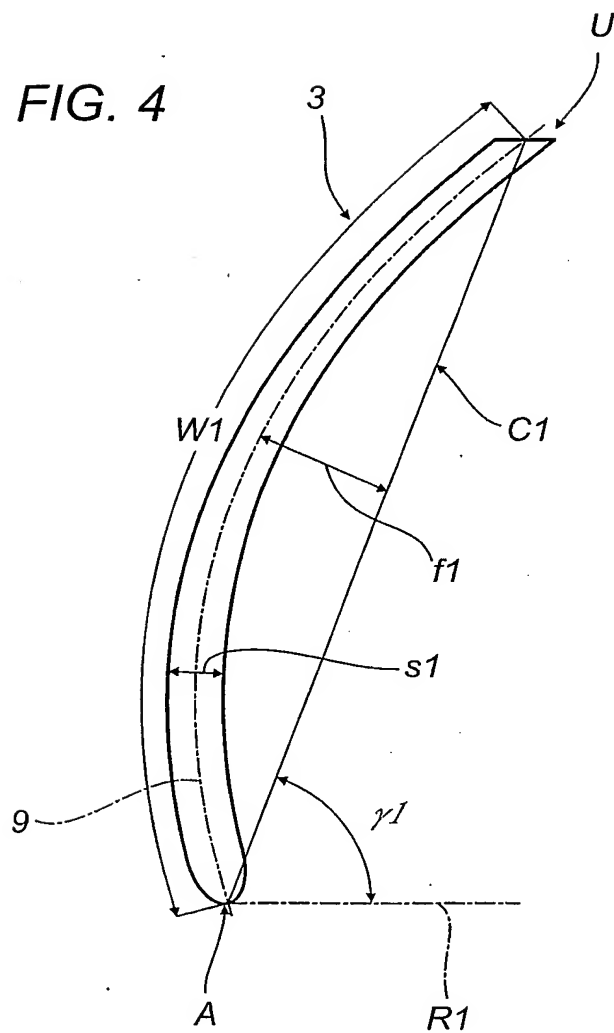
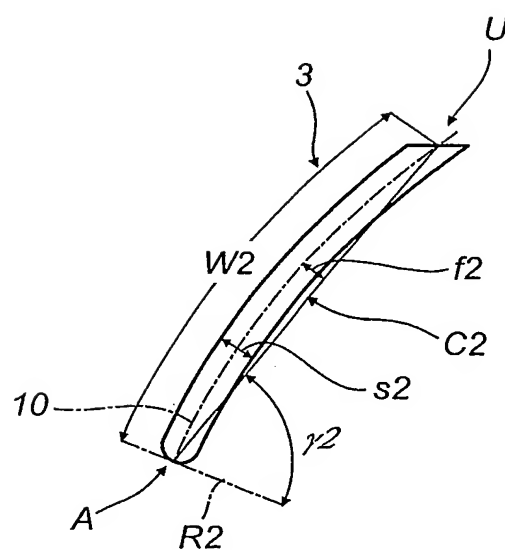


FIG. 5



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FIG. 6

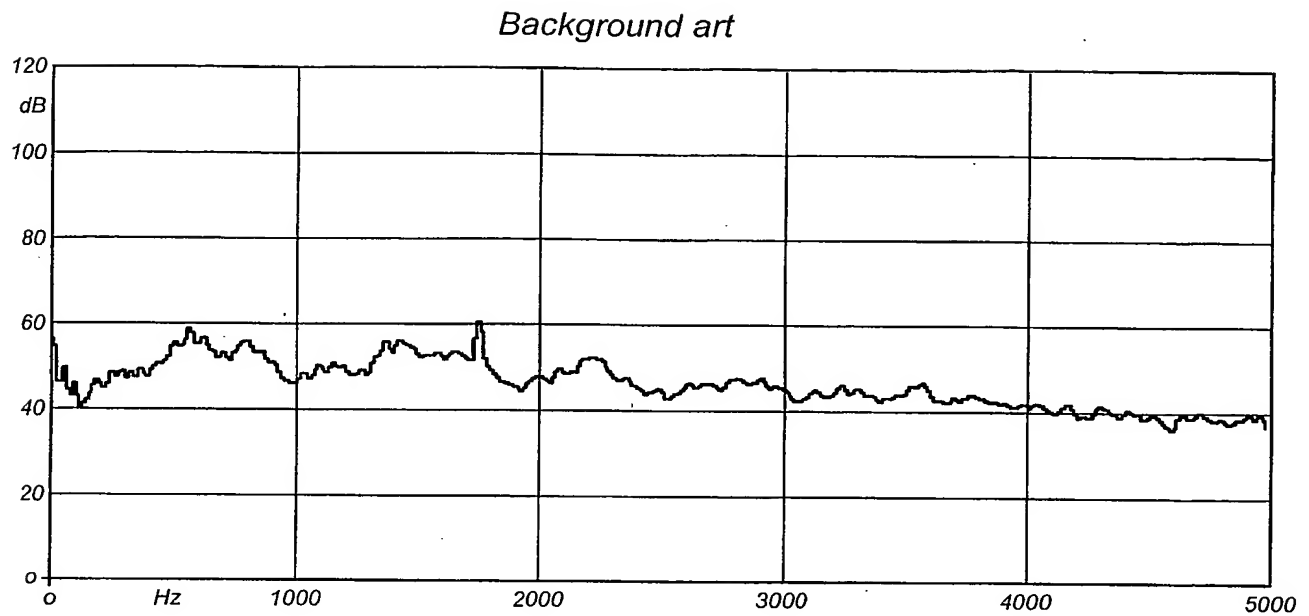
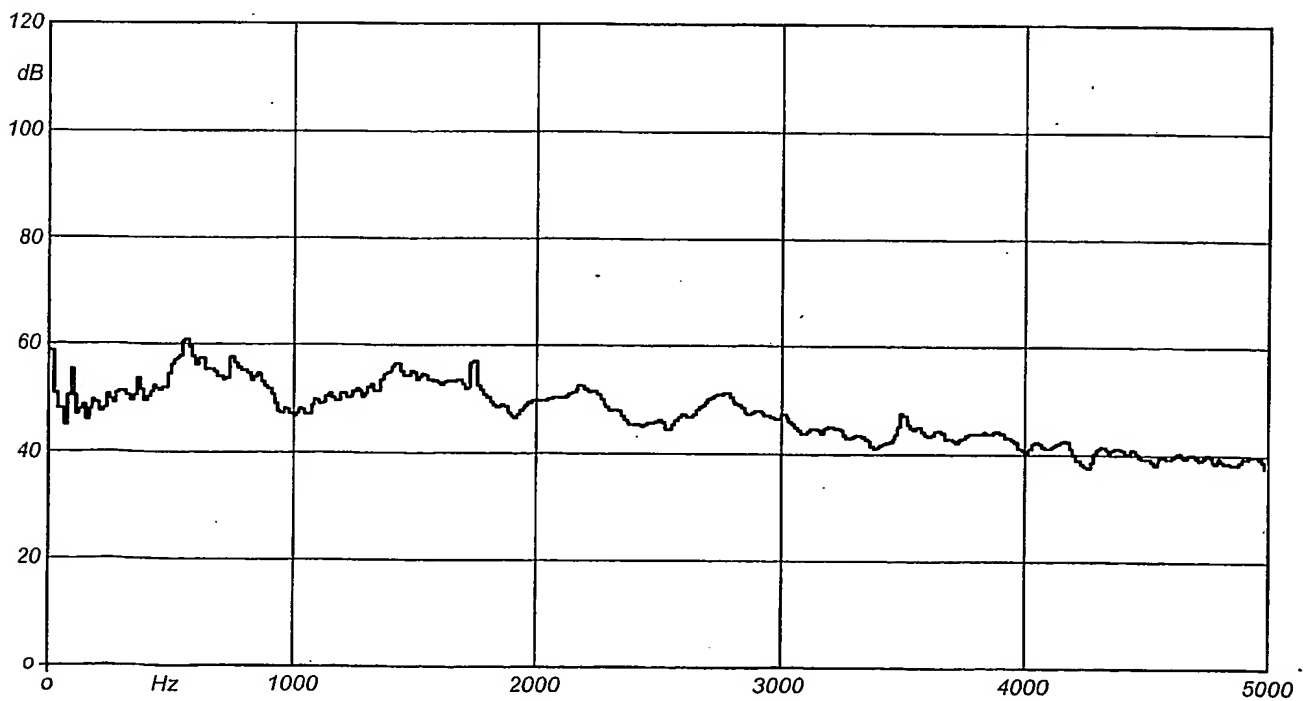


FIG. 7

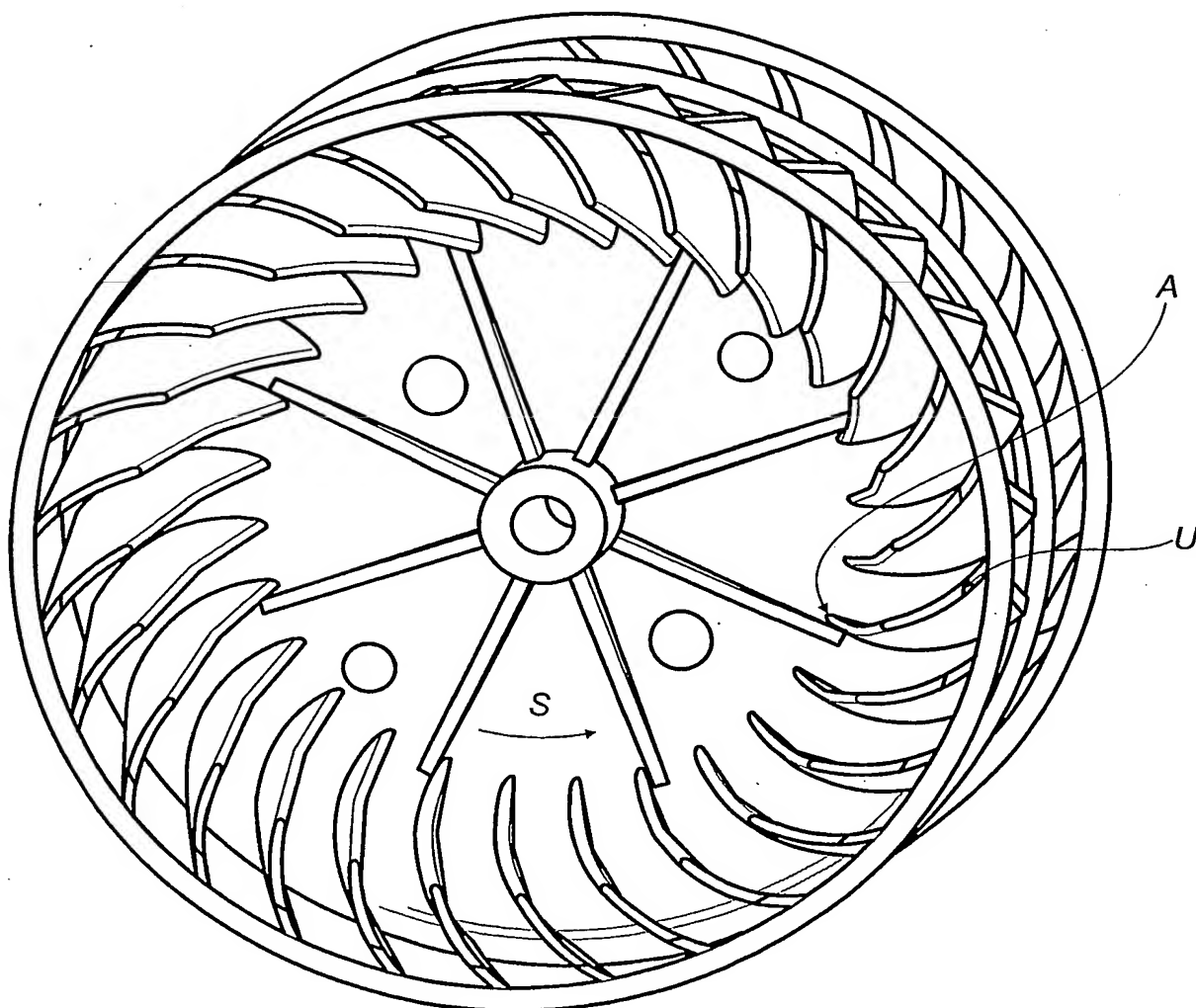


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FIG. 8



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# INTERNATIONAL SEARCH REPORT

International Application No.

PC., -B 03/03207

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F04D29/28 F04D29/30 F04D29/66

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 980 990 A (SPOUSE LOWELL E) 25 April 1961 (1961-04-25) column 3, line 53 - line 65; figure 1	1,4
Y	---	3,5,6,9
Y	US 1 478 909 A (OSWALD RICHARD W) 25 December 1923 (1923-12-25) page 1, line 90 - line 96; figure 3	3,5,6
Y	US 2002/021967 A1 (KIM SUNG CHUN ET AL) 21 February 2002 (2002-02-21) figure 7	3,5,6
Y	US 4 526 506 A (HAAS UDO ET AL) 2 July 1985 (1985-07-02) column 9, line 48 -column 10, line 24	9
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

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Date of the actual completion of the international search

21 October 2003

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28/10/2003

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## INTERNATIONAL SEARCH REPORT

International Application No

PC., IB 03/03207

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 37 08 130 A (BRAUN AG) 22 September 1988 (1988-09-22) column 3, line 61 - line 65; figure 4 ----	1
A	DE 23 22 734 A (BUDERUS EISENWERK) 21 November 1974 (1974-11-21) the whole document ----	1
A	DE 197 36 657 A (GEORG KICK FA) 7 May 1998 (1998-05-07) column 2, line 63 - line 66; figure 1 ----	1
A	EP 0 816 687 A (TOKYO SHIBAURA ELECTRIC CO) 7 January 1998 (1998-01-07) cited in the application -----	

## INTERNATIONAL SEARCH REPORT

International Application No

PC 17 AB 03/03207

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2980990	A	25-04-1961	NONE	
US 1478909	A	25-12-1923	NONE	
US 2002021967	A1	21-02-2002	KR 2002014223 A CN 1339658 A JP 2002061597 A	25-02-2002 13-03-2002 28-02-2002
US 4526506	A	02-07-1985	EP 0112932 A1 AT 13711 T DE 3264089 D1	11-07-1984 15-06-1985 11-07-1985
DE 3708130	A	22-09-1988	DE 3708130 A1 ES 1006032 U1	22-09-1988 01-12-1988
DE 2322734	A	21-11-1974	DE 2322734 A1	21-11-1974
DE 19736657	A	07-05-1998	DE 29614608 U1 DE 19639191 A1 DE 19736657 A1 WO 9807991 A1 EP 0856109 A1	12-12-1996 26-02-1998 07-05-1998 26-02-1998 05-08-1998
EP 0816687	A	07-01-1998	JP 10018990 A CN 1173590 A EP 0816687 A2 KR 210291 B1	20-01-1998 18-02-1998 07-01-1998 15-07-1999

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